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The Self-Learning Particle Swarm Optimization approach for routing pickup and delivery of multiple products with material handling in multiple cross-docks

Mu-Chen Chen [a,*], Yu-Hsiang Hsiao [b], Reddivari Himadeep Reddy [c], Manoj Kumar Tiwari [c]

[a] *Department of Transportation and Logistics Management, National Chiao Tung University, 4F, No. 118, Section 1, Chung Hsiao W. Road, Taipei 100, Taiwan, ROC*
[b] *Department of Business Administration, National Taipei University, New Taipei 237, Taiwan, ROC*
[c] *Department of Industrial and Systems Engineering, Indian Institute of Technology, Kharagpur, Kharagpur, West Bengal 721302, India*

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ABSTRACT

Vehicle Routing Problems (VRPs) in distribution centers with cross-docking operations are more complex than the traditional ones. This paper attempts to address the VRP of distribution centers with multiple cross-docks for processing multiple products. In this paper, the mathematical model intends to minimize the total cost of operations subjected to a set of constraints. Due to high complexity of model, it is solved by using a variant of Particle Swarm Optimization (PSO) with a Self-Learning strategy, namely SLPSO. To validate the effectiveness of SLPSO approach, benchmark problems in the literature and test problems are solved by SLPSO.

1. Introduction

Due to the stringent competition in market, personalization has become one of the important strategies for firm survival. The personalization strategy increases the variety of products supplied by firms. Therefore, there is a substantial increase in uncertainty of customer demand, requiring a more efficient logistics system to shorten the order cycle time and improve the service level. Furthermore, supply chain efficiency is an essential factor of firm competitiveness in such a dynamic economic environment. Implementing the cross-docking operations in distribution centers can create an efficient logistics system in supply chains to control the flow of goods.

The Vehicle Routing Problem (VRP) was first discussed in Dantzig and Ramser (1959), where the optimum routing of a fleet of gasoline-delivery trucks was determined by generalization of Travelling Salesman Problem (TSP). The traditional VRP is the broad class of problems where we determine vehicle routing for a group of vehicles operating to serve a set of nodes. The most simple and typical VRP discusses the physical distribution of goods by a fleet of vehicles, which start from a depot to a set of nodes and back to the depot to satisfy the needs. The most general objective is minimization of cost or total distance to be covered with time constraints as well as maximum capacity constraints (Christofides et al., 1979). However, many variants of VRP have been developed over time with increasing complexity. Simultaneous pickup and delivery, number of vehicles, customer requirements, multiple depots, time window constraints, multiple objectives and backhauls are some

* Corresponding author.
E-mail addresses: ittchen@mail.nctu.edu.tw (M.-C. Chen), yhhsiao@mail.ntpu.edu.tw (Y.-H. Hsiao), himadeep.iitkgp@gmail.com (R. Himadeep Reddy), mkt09@hotmail.com (M.K. Tiwari).

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of the variants where researchers have focused upon. Toth and Vigo (2002) have provided a detailed literature review on the evolution of the classical VRP with insights in new variants, formulations and solution approaches.

With the recent trend of warehousing and distribution, the distribution center with multiple cross-docks is one of the important logistics systems. Cross-docking is defined as the continuous journey of a product from its origin to the final destination through a cross-dock without storing products and materials in a distribution center (Apte and Viswanathan, 2000). In a usual cross-docking facility, products are unloaded from pickup vehicles at the inbound doors, sorted, and then loaded to delivery vehicles at respective outbound doors. Holding times of products at a cross-docking facility typically do not exceed 24 h (Yu and Egbelu, 2008; Alpan et al., 2011a). Thus, the biggest advantages of cross-docking are reduced inventory cost and transportation cost. Cross-docking facilities are very useful in the distribution of perishable goods. As well, cross-docks are used for products with high storage costs, and have emerged as one of the most popular cost saving techniques in logistics. There are ample examples of successful application of cross-docking in the real world. Examples include that of Walmart, Toyota, UPS and many more (Stalk et al., 1992).

At a cross-docking terminal as schematically depicted in Fig. 1, inbound pickup vehicles collect different products from respective suppliers and enter the cross-dock. Once docked, products carried by the pickup vehicles are passed through sorting facility, and then they are forwarded to the designated delivery door, where they are loaded onto a delivery vehicle, which serves the dedicated destination. The problem discussed in this paper deals with a VRP with multiple cross-docks servicing in a distribution center. The products passing through the sorting facilities, not only they may be transferred to respective delivery door, but they may also be sent to another cross-dock and transferred to the required delivery door through a material handling facility. This paper highlights the research issue relating routing of inbound and outbound vehicles for the multi-cross-dock system in a distribution center. Capacity and time constraints have been incorporated as well.

The similarities and differences between VRP with multiple cross-docks and multi-depot VRP are discussed as follows. Determining vehicle routing is common to both problems. However, some major distinctions can be made between these two types of problems. In a multi-depot VRP, the distribution company has multiple depots at different locations. Such a problem sequentially involves grouping customers to identify which customers have to be served by a particular depot, assigning customers to several routes from depots so that fleet constraints are not violated, and at last determining the delivery sequence. The general objective of such a problem is minimizing the delivery time or minimizing the number of vehicles needed. Ultimately, efficiency has to be improved in a multi-depot VRP (Ho et al., 2008). For the VRP with multiple cross-docks, we have multiple docks at a single location, where possible movement of products among docks thereby incurring material handling cost. Laporte et al. (1988) proposed transformation of asymmetrical multi-depot VRP into

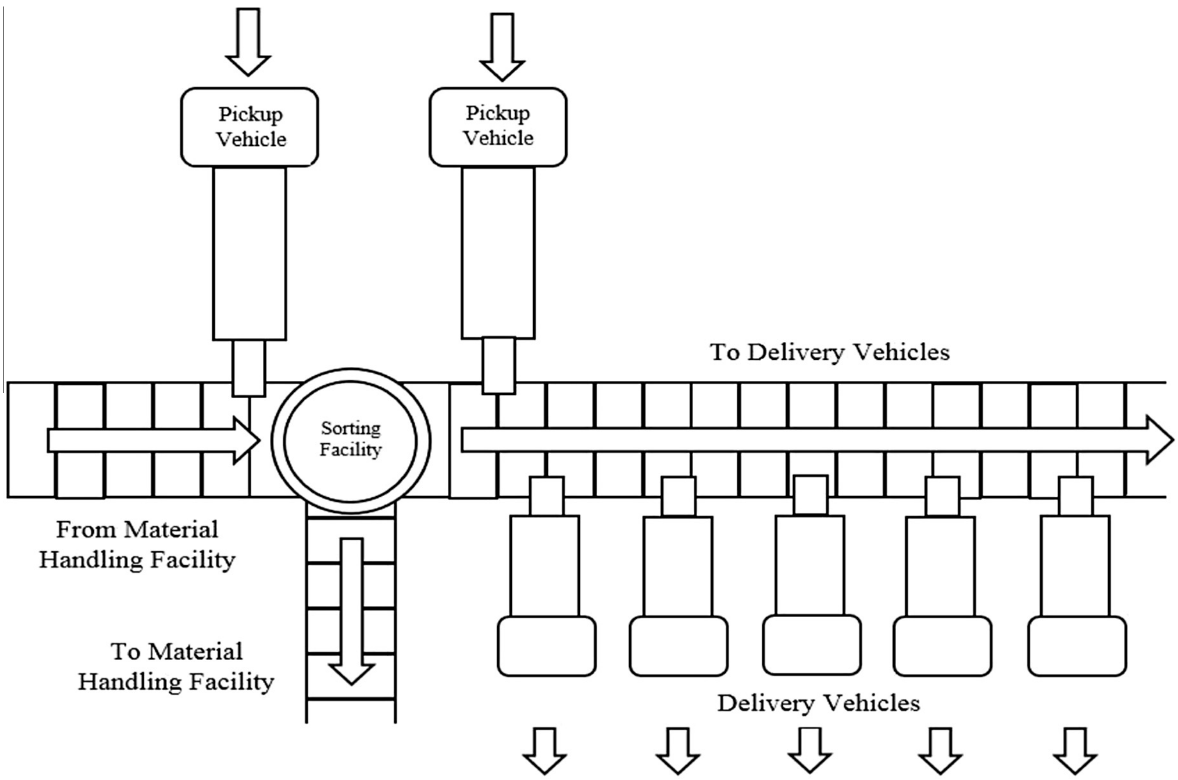

Fig. 1. Functioning of a cross-dock.